

# PATENT ABSTRACTS OF JAPAN

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## (54) METHOD FOR GROWING ALUMINUM COMPOUND SEMICONDUCTOR CRYSTAL

### (57)Abstract:

**PURPOSE:** To attain selective growth of a semiconductor crystal by a vacuum consistent process and to obtain a high quality crystal by using a specified gas as a gaseous organometallic compd. when an Al compd. semiconductor crystal is grown by a molecular beam epitaxial method using the gaseous organometallic compd.

**CONSTITUTION:** An Al compd. semiconductor crystal is grown by a molecular beam epitaxial method using a gaseous organometallic compd. The semiconductor consists preferably of one or more kinds of group III elements of the Periodic Table including Al as an essential component and one or more kinds of group V elements and it is, e.g. AlGaAs. One or more kinds of gaseous organometallic compds. represented by alkyl aluminum, preferably dimethyl aluminum hydride and amine alane preferably dimethylethylamine alane are used as the gaseous organometallic compd.

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CLAIMS

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[Claim(s)]

[Claim 1] It is the crystal growth approach of aluminum system compound semiconductor characterized by the thing of the organic metal gas said organic metal gas is indicated to be by alkylaluminum or Amin Alan in the approach of performing aluminum system compound semiconductor crystal growth using the molecular beam epitaxy method using organic metal gas included for a kind at least.

[Claim 2] It is the crystal growth approach of aluminum system compound semiconductor which said alkylaluminum is a dimethyl aluminum hydride and is characterized by said Amin Alan's being dimethyl ethylamine ARAN in the crystal growth approach according to claim 1.

[Claim 3] It is III to which said aluminum system compound semiconductor uses aluminum as an indispensable component in the crystal growth approach of aluminum system compound semiconductor according to claim 1. The crystal growth approach of aluminum system compound semiconductor characterized by kind and the thing [ a kind ] of V group element of a group element at least at least.

[Claim 4] Setting to the crystal growth approach of aluminum system compound semiconductor according to claim 3, said organic metal gas is said III. III containing a group element It is the crystal growth approach of aluminum system compound semiconductor which consists of mixed gas of group organic metal gas and V group organic metal gas containing said V group element, and is characterized by the value of the mixing ratio of said V group organic metal gas and said III group organic metal gas being less than two.

[Claim 5] The crystal growth approach of aluminum system compound semiconductor characterized by carrying out crystal growth at the temperature of at most 500 degrees C using said organic metal gas in the crystal growth approach of aluminum system compound semiconductor according to claim 3.

[Claim 6] It is the crystal growth approach of aluminum system compound semiconductor characterized by the thing for which said aluminum system compound semiconductor was chosen from AlAs, AlGaAs, and AlGaInAs in the crystal growth approach of aluminum system compound semiconductor according to claim 3, and which is a kind at least.

[Claim 7] It is the crystal growth approach of aluminum system compound semiconductor which consists of a kind at least and is characterized by the thing as which it was chosen from aluminum, Ga, and In in which said III group element surely contains aluminum in the crystal growth approach of aluminum system compound semiconductor according to claim 3, for which said V group element was chosen from among As and N, and which is a kind at least.

[Claim 8] It is the crystal growth approach of aluminum system compound semiconductor characterized by said III group organic metal gas containing an alkyl gallium when said III group element contains Ga in the crystal growth approach of aluminum system compound semiconductor according to claim 7.

[Claim 9] It is the crystal growth approach of aluminum system compound semiconductor that said alkyl gallium is characterized by being a kind of a methyl gallium and the ethyl galliums at least in the crystal growth approach of aluminum system compound semiconductor according to claim 8.

[Claim 10] It is the crystal growth approach of aluminum system compound semiconductor characterized by said V group organic metal gas containing an amino arsine when said V group element contains As in the crystal growth approach of aluminum system compound semiconductor according to claim 7.

[Claim 11] It is the crystal growth approach of aluminum system compound semiconductor characterized by said amino arsine being a tris dimethylamino arsine in the crystal growth approach of aluminum system compound semiconductor according to claim 10.

[Claim 12] It is the crystal growth approach of aluminum system compound semiconductor characterized by being the alternative crystal growth of aluminum system compound semiconductor used for the multi-chamber process for which said crystal growth used the GaN mask and the GaAs oxide mask in the crystal growth approach of aluminum system compound semiconductor a publication either claim 1 thru/or of 11.

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DETAILED DESCRIPTION

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[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention -- the molecular beam epitaxy (Metal organic molecular beam epitaxy, MOMBE) of organic metal gas utilization -- it is related with the crystal growth of aluminum system compound semiconductor using law.

[0002]

[Description of the Prior Art] the molecular beam epitaxy (MOMBE) using former and organic metal gas -- the crystal growth of compound semiconductors, such as AlAs, AlGaAs, etc. which used law, -- setting -- as the material gas of aluminum -- as trimethylaluminum (hereafter referred to as TMA), and As raw material -- As<sub>4</sub> It has been used.

[0003] According to the verification experiment of this invention persons, crystal growth, such as AlAs, was tried at the growth temperature of 600 degrees C here using these material gas, but a flat crystal plane was not obtained.

Furthermore, a GaAs oxide mask is used and they are AlAs or AlGaAs to opening of a GaAs oxidation mask TMA and As<sub>4</sub> When it uses and selective growth is tried, AlAs accumulates on a mask and selective growth is impossible.

[0004]

[Problem(s) to be Solved by the Invention] As mentioned above, the crystal growth of aluminum system compound semiconductors, such as AlAs which has a smooth front face using the MOMBE method, was difficult.

[0005] Moreover, the selective growth of compound semiconductors, such as AlAs using the multi-chamber process, was unrealizable.

[0006] furthermore, MOMBE of compound semiconductors, such as AlAs, -- the combination of the material gas for realizing crystal growth by law was not clear.

[0007] then, the technical technical problem of this invention -- MOMBE -- it is in realizing selective growth of the compound semiconductor of aluminum system using [ and ] the multi-chamber process for the purpose of obtaining a good crystal in the crystal growth of aluminum system compound semiconductor using law.

[0008]

[Means for Solving the Problem] According to this invention, in the approach of performing aluminum system compound semiconductor crystal growth using the molecular beam epitaxy method using organic metal gas, the crystal growth approach of aluminum system compound semiconductor characterized by the thing of the organic metal gas said organic metal gas is indicated to be by alkylaluminum or Amin Alan included for a kind at least is acquired.

[0009] the organometallic compound indicated to be alkylaluminum by R<sub>1</sub> AlH (R<sub>2</sub>) in this invention here -- it is -- R<sub>1</sub> And R<sub>2</sub> CH<sub>3</sub> and C two H<sub>5</sub> etc. -- it is an aliphatic hydrocarbon compound. Moreover, it sets to this invention and Amin Alan is R<sub>3</sub> NAlH (R(R<sub>4</sub>) 5)3. It is the compound shown, R<sub>3</sub> N (R(R<sub>4</sub>) 5) is the 3rd amine, and it is R<sub>3</sub>, R<sub>4</sub>, and R<sub>5</sub>. It is the functional group of H or aliphatic hydrocarbon, respectively. And said alkylaluminum is a dimethyl aluminum hydride (CH<sub>3</sub>) (referred to as DMAIH 2 AlH and the following), and, as for said Amin Alan, it is desirable that it is dimethyl ethylamine ARAN (CH<sub>3</sub>) (2 C<sub>2</sub> H<sub>5</sub> NAlH<sub>3</sub>).

[0010] Moreover, it is III to which said aluminum system compound semiconductor uses aluminum as an indispensable component in the crystal growth approach of said aluminum system compound semiconductor according to this invention. The crystal growth approach of aluminum system compound semiconductor characterized by kind and the thing [ a kind ] of V group element of a group element at least is acquired.

[0011] Moreover, according to this invention, it sets to the crystal growth approach of said aluminum system compound semiconductor, and said organic metal gas is said III. III containing a group element It consists of mixed gas of group organic metal gas and V group organic metal gas containing said V group element, and the crystal growth approach of aluminum system compound semiconductor characterized by the value of the mixing ratio of said V group organic metal gas and said III group organic metal gas being less than two is acquired.

[0012] Moreover, according to this invention, in the crystal growth approach of said aluminum system compound semiconductor, the crystal growth approach of aluminum system compound semiconductor characterized by carrying out crystal growth at the temperature of at most 500 degrees C using said organic metal gas is acquired.

[0013] Moreover, according to this invention, in the crystal growth approach of said aluminum system compound semiconductor, the crystal growth approach of aluminum system compound semiconductor characterized by the thing for which said aluminum system compound semiconductor was chosen from AlAs, AlGaAs, and AlGaInAs, and which is a kind at least is acquired.

[0014] Moreover, according to this invention, in the crystal growth approach of said aluminum system compound semiconductor, it consists of a kind at least and the crystal growth approach of aluminum system compound semiconductor characterized by the thing as which said III group element was chosen from aluminum, Ga, and In which

surely contain aluminum, for which said V group element was chosen from among As and N, and which is a kind at least is acquired.

[0015] Moreover, when said III group element contains Ga in the crystal growth approach of said aluminum system compound semiconductor according to this invention, the crystal growth approach of aluminum system compound semiconductor characterized by said III group organic metal gas containing an alkyl gallium is acquired.

[0016] It sets here to the crystal growth approach of said aluminum system compound semiconductor of this invention. Said alkyl gallium It is shown by general formula  $R_6Ga(R_7)_8$  (7 however,  $R_6, R_7, R_8$  functional group of hydrogen or aliphatic hydrocarbon). Also in it Trimethylgallium ( $CH_3$ ) (3 Ga), And it is desirable that it is a kind at least of the triethylgallium ( $C_2H_5$ ) (3 Ga).

[0017] Moreover, when said V group element contains As in the crystal growth approach of said aluminum system compound semiconductor according to this invention, the crystal growth approach of aluminum system compound semiconductor characterized by said V group organic metal gas containing an amino arsine is acquired. It sets here to the crystal growth approach of said aluminum system compound semiconductor of this invention. Said amino arsines  $Am_1As(Am_2)Am_3$  (however,  $Am_1, Am_2, Am_3$  are primary amine)  $CH_3$  which contains H for  $R_9, R_{10}$  and  $R_{11}$ , and C two  $H_5$  etc. -- when it considers as the functional group of aliphatic hydrocarbon, it is the compound shown by  $R_9NR_{10}R_{11}$ , and it is desirable especially that it is a tris dimethylamino arsine  $\{As[N(CH_3)_2]_3\}$ .

[0018] Furthermore, according to this invention, in the crystal growth approach of one of said aluminum system compound semiconductors, the crystal growth approach of aluminum system compound semiconductor characterized by said crystal growth being the alternative crystal growth of aluminum system compound semiconductor used for the multi-chamber process which used the GaN mask and the GaAs oxide mask is acquired.

[0019]

[Example] The example of this invention is explained with reference to a drawing below.

[0020] (Example 1) aluminum NIUMUHI drawing 1 is drawing showing each process of the crystal growth approach of (Aluminum aluminum) system compound semiconductor concerning the example 1 of this invention in order, and using the gallium nitride (GaN) mask -- the selective growth using the multi-chamber process of base (AlAs) is shown.

[0021] After removing the natural oxidation film of substrate 1 front face first in super-vacuum devices with reference to drawing 1 (a) using the substrate 1 of GaAs (100), epitaxial growth of GaAs is performed at the substrate temperature of 580 degrees C. the substrate temperature after growing GaAs epitaxially -- As draft -- up to 640 degrees C -- raising -- a GaAs front face -- a gallium -- it considers as a rich (Ga rich) field (1x1) (Ga side). the dimethylhydrazine (DMAH) which serves as a source of nitrogen (N) at this time is introduced, and As \*\* is cut. By this, the thin film 2 of cubic GaN which has the thickness of about 20A is formed. As shown in drawing 1 (b) after GaN formation, Ga4 is locally attached to opening of the metal mask 3 using the metal mask 3. After attaching Ga4, as the metal mask 3 is removed as shown in drawing 1 (c), and substrate temperature is raised to 610 degrees C and shown in drawing 1 (d), some thin films 2 of GaN which attached Ga4 are removed alternatively, and it carries out patterning. Pore 2a is formed in drawing 1 (d). after it carries out patterning, using the thin film 2 of GaN as a mask, it is shown in drawing 1 (e) -- as -- substrate temperature -- 430 degrees C -- carrying out -- a dimethyl aluminum hydride (DMAIH) -- a tris dimethylamino arsine (TDMAs) -- using -- aluminum NIUMUHI -- selective growth of base (AlAs) 5 was performed. Namely, it introduced in ultra-high-vacuum equipment by setting TDMAs to  $1.0 \times 10^{-7}$ Torr, having set DMAIH as  $1.5 \times 10^{-7}$ Torr. Consequently, selective growth of AlAs5 was able to be carried out only to field 2a in which the mask (it is hereafter called the GaN mask 2) which consists of a thin film 2 of GaN carried out patterning. Moreover, AlAs did not accumulate on the GaN mask 2. The combination of the above thing to DMAIH and TDMAs was effective in the crystal growth of AlAs.

[0022] When selective growth of AlAs was performed [ in / with the occasion / the complete growth on a GaAs substrate ] at the growth temperature of 500 degrees C or less in a flow and pressure requirement same as the above using DMAIH and TDMAs, the smooth growth side of AlAs was acquired. Moreover, when growth temperature was made into 500 degrees C or more, it was ruined and a good crystal front face was not obtained.

[0023] Furthermore, it is DMAIH and As4 because of the example of a comparison. Growth of AlAs was also tried and seen in combination. In this case, it is DMAIH  $1.5 \times 10^{-7}$ Torr and As4 Although it was referred to as  $1.5 \times 10^{-6}$ Torr, growth temperature was changed and growth of AlAs was tried, the smooth front face was obtained at no growth temperature.

[0024] Therefore, in the example 1 of this invention, using DMAIH and TDMAs, when AlAs was completely grown up at the growth temperature of 500 degrees C or less, the smooth front face was able to be obtained.

[0025] Moreover, although  $1.5 \times 10^{-7}$ Torr installation of the trimethylgallium (TMG) was carried out and complete growth of the mixed crystal of AlGaAs was further tried on the conditions of an example 1 as an application of the example 1 of this invention, the very smooth front face was able to be obtained also in this case. Therefore, the result effective also in the crystal growth of AlGaAs which combined DMAIH and TMG adapting an example 1, and TDMAs was able to be obtained.

[0026] (Example 2) In the example 2, it changed to the GaN mask of an example 1, and selective growth of AlAs by the same multi-chamber process was performed except having used the GaAs oxide film. First, that procedure introduces the oxygen gas of 10Torr(s) in vacuum devices on a GaAs (100) substrate, and forms a GaAs oxide film in this substrate front face by the optical exposure of a halogen lamp. Thermal desorption of the GaAs oxide film which attached Metal Ga locally on the mask after oxide-film formation, and attached Ga at 540 degrees C after that was carried out. By this, opening was prepared in the GaAs oxide film. Then, DMAIH and TDMAs were introduced in ultra-high-vacuum equipment, and the substrate temperature of 430 degrees C and the selective growth of AlAs were tried. Consequently, only opening of a GaAs oxide film was able to perform selective growth of AlAs.

[0027] (Example 3) It was made to be the same as that of an example 1 and an example 2 instead of the combination of DMAIH and TDMAAs using the GaN mask or the GaAs oxidization mask except having used the combination of dimethyl ethylamine ARAN (CH<sub>3</sub>)<sub>2</sub> C<sub>2</sub> H<sub>5</sub> NAlH<sub>3</sub> and TDMAAs. Consequently, the selective growth of AlAs was realizable.

[0028] (Example 4) Like the above-mentioned example 1 thru/or 3, in the selective growth of AlGaAs, it was able to consider as trimethylgallium (TMG) or triethylgallium (TEG) as a source of Ga as a combination of material gas, was able to consider as a dimethyl aluminum hydride (DMAIH) or dimethyl ethylamine ARAN as a source of aluminum, and was able to carry out further again, using a tris dimethylamino arsine (TDMAAs) as a source of As.

[0029] In addition, this invention is applicable also to the crystal growth of all the compound semiconductors of aluminum systems, such as AlAs, AlGaAs, AlN, and AlGaN.

[0030]

[Effect of the Invention] As mentioned above, as explained, in this invention, the crystal growth approach of aluminum system compound semiconductor which the selective growth using the multi-chamber process by the compound semiconductor of aluminum system of becomes possible, and the structure creation of the optical device which aims at the fine structure, or an electron device of is attained, and is greatly industrially useful can be offered.

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**DESCRIPTION OF DRAWINGS**

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[Brief Description of the Drawings]

[Drawing 1] (a) - (e) is a sectional view which \*\* each process of the crystal growth approach of aluminum system compound semiconductor concerning the example 1 of this invention in order.

[Description of Notations]

- 1 Substrate
- 2 Thin Film
- 3 Metal Mask
- 4 Gallium (Ga)
- 5 Aluminum NIUMUHI -- Base (AlAs)

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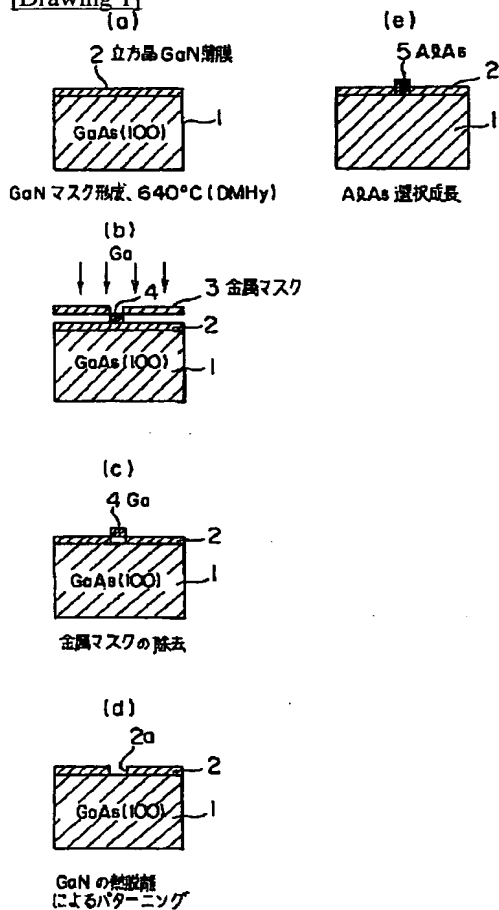
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## DRAWINGS

[Drawing 1]



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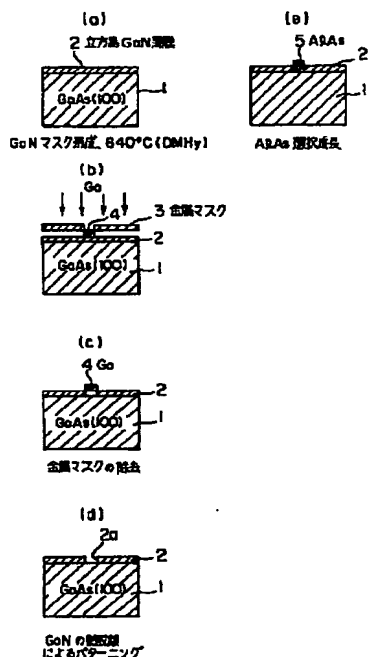
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(54)【発明の名称】 A1系化合物半導体の結晶成長方法

(57)【要約】

【目的】 有機金属を用いた分子線エビタキシー (MO MBE) 法を用いるA1系化合物半導体の結晶成長において、良質の結晶を得、かつ真空一貫プロセスを用いるA1系の化合物半導体の選択成長を実現する。

【構成】 ジメチルアルミニウムハイドライド又はジメチルエチルアミノアランを含む有機金属ガスをを用いた分子線エビタキシー法を用いるA1系化合物半導体の結晶成長を行う。





## 【特許請求の範囲】

【請求項1】 有機金属ガスを用いた分子線エビタキシー法を用いるA1系化合物半導体結晶成長を行う方法において、前記有機金属ガスは、アルキルアルミニウム類又はアミンアラン類によって示される有機金属ガスの少なくとも一種を含むことを特徴とするA1系化合物半導体の結晶成長方法。

【請求項2】 請求項1記載の結晶成長方法において、前記アルキルアルミニウムは、ジメチルアルミニウムハイドライドであり、前記アミンアラン類はジメチルエチルアミンアランであることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項3】 請求項1記載のA1系化合物半導体の結晶成長方法において、前記A1系化合物半導体は、A1を必須成分とするIII族元素の少なくとも一種と、V族元素の少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項4】 請求項3記載のA1系化合物半導体の結晶成長方法において、前記有機金属ガスは、前記III族元素を含むIII族有機金属ガスと、前記V族元素を含むV族有機金属ガスとの混合ガスからなり、前記V族有機金属ガスと前記III族有機金属ガスとの混合比の値は、2未満であることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項5】 請求項3記載のA1系化合物半導体の結晶成長方法において、前記有機金属ガスを用いて多くとも500℃の温度で結晶成長させることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項6】 請求項3記載のA1系化合物半導体の結晶成長方法において、前記A1系化合物半導体は、AlAs、AlGaAs、及びAlGaInAsから選択された少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項7】 請求項3記載のA1系化合物半導体の結晶成長方法において、前記III族元素はA1を必ず含むAl、Ga、Inから選択された少なくとも一種からなり、前記V族元素は、As及びNのうちから選択された少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項8】 請求項7記載のA1系化合物半導体の結晶成長方法において、前記III族元素がGaを含む場合、前記III族有機金属ガスは、アルキルガリウムを含むことを特徴とするA1系化合物半導体の結晶成長方法。

【請求項9】 請求項8記載のA1系化合物半導体の結晶成長方法において、前記アルキルガリウムは、メチルガリウム及びエチルガリウムの内の少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項10】 請求項7記載のA1系化合物半導体の

結晶成長方法において、前記V族元素がAsを含む場合、前記V族有機金属ガスは、アミノアルシンを含むことを特徴とするA1系化合物半導体の結晶成長方法。

【請求項11】 請求項10記載のA1系化合物半導体の結晶成長方法において、前記アミノアルシンは、トリスジメチルアミノアルシンであることを特徴とするA1系化合物半導体の結晶成長方法。

【請求項12】 請求項1乃至11の内のいずれか記載のA1系化合物半導体の結晶成長方法において、前記結晶成長は、GaNマスクとGaAs酸化物マスクを用いた真空一貫プロセスに用いるA1系化合物半導体の選択的結晶成長であることを特徴とするA1系化合物半導体の結晶成長方法。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】本発明は、有機金属ガス利用の分子線エビタキシー（Metal organic molecular beam epitaxy, MOMB E）法を用いたA1系化合物半導体の結晶成長に関する。

## 【0002】

【従来の技術】従来、有機金属ガスを用いた分子線エビタキシー（MOMB E）法を使用したAlAs、AlGaAs等の化合物半導体の結晶成長において、Alの原料ガスとして、トリメチルアルミニウム（以下、TMAと呼ぶ）、As原料としてAs<sub>4</sub>が用いられてきた。

【0003】ここで、本発明者らの検証実験によると、これらの原料ガスを用いてAlAs等の結晶成長を成長温度600℃で試みたが、平坦な結晶平面が得られなかった。更に、GaAs酸化膜マスクを用い、GaAs酸化マスクの開口部にAlAs又はAlGaAsをTM A、As<sub>4</sub>を用いて選択成長を試みた場合、AlAsがマスク上に堆積し、選択成長ができなくなってしまった。

## 【0004】

【発明が解決しようとする課題】上述したように、MOMB E法を用いてスムーズな表面を持つAlAs等のA1系化合物半導体の結晶成長は困難であった。

【0005】また、真空一貫プロセスを用いるAlAs等の化合物半導体の選択成長が実現できなかった。

【0006】さらに、AlAs等の化合物半導体のMOMB E法による結晶成長を実現するための原料ガスの組み合わせが明らかではなかった。

【0007】そこで、本発明の技術的課題は、MOMB E法を用いるA1系化合物半導体の結晶成長において、良質の結晶を得ることを目的とし、かつ真空一貫プロセスを用いるA1系の化合物半導体の選択成長を実現することにある。

## 【0008】

【課題を解決するための手段】本発明によれば、有機金属ガスを用いた分子線エビタキシー法を用いるA1系化

合物半導体結晶成長を行う方法において、前記有機金属ガスは、アルキルアルミニウム類又はアミンアラン類によって示される有機金属ガスの少なくとも一種を含むことを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0009】ここで、本発明において、アルキルアルミニウム類とは、 $R_1(R_2)AlH$ で示される有機金属化合物で、 $R_1$ 及び $R_2$ は、 $CH_3$ 、 $C_2H_5$ 等の脂肪族炭化水素化合物である。また、本発明において、アミンアラン類とは、 $R_1(R_2)(R_3)NAIH$ で示される化合物で、 $R_1(R_2)(R_3)N$ は第3アミンで、 $R_1$ 、 $R_2$ 、及び $R_3$ は夫々、 $H$ 又は脂肪族炭化水素の官能基である。そして、前記アルキルアルミニウムは、ジメチルアルミニウムハイドライド( $(CH_3)_2AlH$ 、以下、DMAIHと呼ぶ)であり、前記アミンアラン類はジメチルエチルアミンアラン( $(CH_3)_2C_2H_5NAIH$ )であることが好ましい。

【0010】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記A1系化合物半導体は、A1を必須成分とするIII族元素の少なくとも一種と、V族元素の少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0011】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記有機金属ガスは、前記III族元素を含むIII族有機金属ガスと、前記V族元素を含むV族有機金属ガスとの混合ガスからなり、前記V族有機金属ガスと前記III族有機金属ガスとの混合比の値は、2未満であることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0012】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記有機金属ガスを用いて多くとも500℃の温度で結晶成長させることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0013】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記A1系化合物半導体は、 $AlAs$ 、 $AlGaAs$ 、及び $AlGaInAs$ から選択された少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0014】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記III族元素はA1を必ず含むAl、Ga、Inから選択された少なくとも一種からなり、前記V族元素は、As及びNのうちから選択された少なくとも一種であることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0015】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記III族元素がGaを含む場合、前記III族有機金属ガスは、アルキルガリウムを含むことを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0016】ここで、本発明の前記A1系化合物半導体の結晶成長方法において、前記アルキルガリウムは、一般式 $R_1(R_2)(R_3)Ga$ (但し、 $R_1$ 、 $R_2$ 、 $R_3$ は水素又は脂肪族炭化水素の官能基)で示され、その中でもトリメチルガリウム( $(CH_3)_3Ga$ )、及びトリエチルガリウム( $(C_2H_5)_3Ga$ )の内の少なくとも一種であることが好ましい。

【0017】また、本発明によれば、前記A1系化合物半導体の結晶成長方法において、前記V族元素がAsを含む場合、前記V族有機金属ガスは、アミノアルシンを含むことを特徴とするA1系化合物半導体の結晶成長方法が得られる。ここで、本発明の前記A1系化合物半導体の結晶成長方法において、前記アミノアルシン類は、 $Am_1As(Am_2)Am_3$ (但し、 $Am_1$ 、 $Am_2$ 、 $Am_3$ は第1アミンで、 $R_1$ 、 $R_{10}$ 、 $R_{11}$ をHを含む $CH_3$ 、 $C_2H_5$ 等の脂肪族炭化水素の官能基としたときに、 $R_1(R_{10})NR_{11}$ で示される化合物であり、特に、トリスジメチルアミノアルシン $\{As[N(CH_3)_2]_3\}$ であることが好ましい。

【0018】更に、本発明によれば、前記いずれかのA1系化合物半導体の結晶成長方法において、前記結晶成長は、GaNマスクとGaAs酸化物マスクを用いた真空一貫プロセスに用いるA1系化合物半導体の選択的結晶成長であることを特徴とするA1系化合物半導体の結晶成長方法が得られる。

【0019】

【実施例】以下に本発明の実施例について図面を参照して説明する。

【0020】(実施例1)図1は本発明の実施例1に係るアルミニウム(A1)系化合物半導体の結晶成長方法の各工程を順に示す図で、窒化ガリウム(GaN)マスクを用いたアルミニウムヒ素( $AlAs$ )の真空一貫プロセスを用いる選択成長について示してある。

【0021】図1(a)を参照して、 $GaAs(100)$ の基板1を用い、超真空装置内において先ず基板1表面の自然酸化膜を除去した後、基板温度580℃でGaAsのエピタキシャル成長を行う。GaAsをエピタキシャル成長した後、基板温度をAs圧下で640℃まで上げて、GaAs表面をガリウムリッチ(Ga rich)な面( $(1 \times 1)Ga$ 面)とする。このとき窒素(N)源となるジメチルヒドラジン(DMH<sub>2</sub>)を導入し、As圧をきる。これによって、20オングストローム程度の厚さを有する立方晶のGaNの薄膜2を形成する。GaN形成後、図1(b)に示すように、金属マスク3を用いてGa4を金属マスク3の開口部に局所的につける。Ga4を付けた後、図1(c)に示すように金属マスク3を外して、基板温度を610℃まで上昇させ、図1(d)に示すように、Ga4を付けたGaNの薄膜2の一部を選択的に除去し、パターニングする。図1(d)においては、孔部2aが形成されている。Ga

Nの薄膜2をマスクとしてパターンニングした後、図1(e)に示すように、基板温度を430℃とし、ジメチルアルミニウムハイドライド(DMA1H)をトリスジメチルアミノアルシン(TDMAAs)を用いてアルミニウムヒ素(AlAs)5の選択成長を行った。即ち、DMA1Hを $1.5 \times 10^{-7}$  Torr, TDMAAsを $1.0 \times 10^{-7}$  Torrとして、超高真空装置内に導入した。その結果、AlAs5をGa<sub>0.5</sub>Nの薄膜2からなるマスク(以下、Ga<sub>0.5</sub>Nマスク2と呼ぶ)のパターンニングした領域2aのみに選択成長を行うことができた。また、Ga<sub>0.5</sub>Nマスク2上には、AlAsは堆積しなかった。以上のことから、DMA1HとTDMAAsの組み合わせは、AlAsの結晶成長に有効であった。

【0022】ついでながら、AlAsの選択成長は、GaAs基板上の全面成長において、DMA1HとTDMAAsを用いて同上の圧力条件において、500℃以下の成長温度で行なったとき、AlAsのスムーズな成長面が得られた。又、成長温度を500℃以上にするとAlAsの成長表面は荒れて良好な結晶表面が得られなかった。

【0023】更に、比較例の為に、DMA1HとAs<sub>2</sub>の組み合わせでAlAsの成長も試みて見た。この場合、DMA1Hを $1.5 \times 10^{-7}$  Torr, As<sub>2</sub>を $1.5 \times 10^{-6}$  Torrとして、成長温度を変えてAlAsの成長を試みたが、どの成長温度でもスムーズな表面が得られなかった。

【0024】したがって、本発明の実施例1においては、DMA1HとTDMAAsを用いて、成長温度500℃以下でAlAsを全面成長した場合においてのみ、スムーズな表面を得ることができた。

【0025】また、本発明の実施例1の応用例として、実施例1の条件に、更に、トリメチルガリウム(TM<sub>3</sub>G)を $1.5 \times 10^{-7}$  Torr導入し、AlGaAsの混晶の全面成長を試みたが、この場合も、非常にスムーズな表面を得ることができた。したがって、実施例1を応用したDMA1H, TM<sub>3</sub>G, 及びTDMAAsを組み合わせたAlGaAsの結晶成長にも有効な結果を得ることができた。

【0026】(実施例2) 実施例2においては、実施例1のGa<sub>0.5</sub>Nマスクに換えて、GaAs酸化膜を用いた以外は同様な真空一貫プロセスによるAlAsの選択成長を行った。その手順は、まず、GaAs(100)基板上に10 Torrの酸素ガスを真空装置内に導入し、こ

の基板表面にGaAs酸化膜をハロゲンランプの光照射によって形成する。酸化膜形成後、メタルGaをマスク上に局所的に付け、その後540℃でGaを付けたGaAs酸化膜を熱脱離させた。これによって、GaAs酸化膜に開口部を設けた。その後、DMA1HとTDMAAsを超高真空装置内に導入し、基板温度430℃、AlAsの選択成長を試みた。その結果、GaAs酸化膜の開口部のみAlAsの選択成長を行うことができた。

【0027】(実施例3) Ga<sub>0.5</sub>Nマスク、又はGaAs酸化マスクを用い、DMA1HとTDMAAsの組み合わせの代わりに、ジメチルエチルアミンアラン((CH<sub>3</sub>)<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>AlH<sub>2</sub>)とTDMAAsの組み合わせを用いた以外は、実施例1及び実施例2と同様にした。その結果、AlAsの選択成長が実現できた。

【0028】(実施例4) また、上記実施例1乃至3と同様に、AlGaAsの選択成長において、原料ガスの組み合わせとして、Ga源としてトリメチルガリウム(TM<sub>3</sub>G)、又はトリエチルガリウム(TEG)とし、Al源としては、ジメチルアルミハイドライド(DMA1H)又はジメチルエチルアミンアランとし、さらにAs源としては、トリスジメチルアミノアルシン(TDMAAs)を用いて行うことができた。

【0029】尚、本発明はAlAs, AlGaAs, Al<sub>0.5</sub>N, Al<sub>0.5</sub>GaN等のAl系のすべての化合物半導体の結晶成長にも応用できる。

【0030】

【発明の効果】以上、説明したように、本発明においては、Al系の化合物半導体による真空一貫プロセスを用いる選択成長が可能となり、微細構造を目指す光デバイス、又は電子デバイスの構造作成が可能となり工業的に大いに役立つAl系化合物半導体の結晶成長方法を提供することができる。

【図面の簡単な説明】

【図1】(a)～(e)は本発明の実施例1に係るAl系化合物半導体の結晶成長方法の各工程を順に示す断面図である。

【符号の説明】

- 1 基板
- 2 薄膜
- 3 金属マスク
- 4 ガリウム(Ga)
- 5 アルミニウムヒ素(AlAs)

【図 1】

